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Risk indicators associated with root caries in independently living older adults

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ABSTRACT

Objective: To determine the risk indicators associated with root caries experience in a cohort of independently living older adults in Ireland.
Methods: The data reported in the present study were obtained from a prospective longitudinal study conducted in a cohort of independently living older adults (n = 334). Each subject underwent an oral examination, performed by a single calibrated examiner, to determine the root caries index and other clinical variables. Questionnaires were used to collect data on oral hygiene habits, diet, smoking and alcohol habits and education level. A regression analysis with the outcome variable of root caries experience (no/yes) was conducted.
Results: A total of 334 older dentate adults with a mean age of 69.1 years were examined. 53.3% had at least one filled or decayed root surface. The median root caries index was 3.13 (IQR 0.00, 13.92). The results from the multivariate regression analysis indicated that individuals with poor plaque control (OR 9.59, 95% CI 3.84–24.00), xerostomia (OR 18.49, 95% CI 2.00–172.80), two or more teeth with coronal decay (OR 4.50, 95% CI 2.02–10.02) and 37 or more exposed root surfaces (OR 5.48, 95% CI 2.49–12.01) were more likely to have been affected by root caries.
Conclusions: The prevalence of root caries was high in this cohort. This study suggests a correlation between root caries and the variables poor plaque control, xerostomia, coronal decay (≥2 teeth affected) and exposed root surfaces (≥37). The significance of these risk indicators and the resulting prediction model should be further evaluated in a prospective study of root caries incidence.
Clinical significance: Identification of risk indicators for root caries in independently living older adults would facilitate dental practitioners to identify those who would benefit most from interventions aimed at prevention.

1. Introduction

In many industrialised countries, as birth rates fall and life expectancy increases, the proportion of older adults within the general population is increasing. This trend is predicted to continue at pace in the twenty first century [1]. While the prevalence of chronic medical conditions is high in this cohort, large longitudinal population studies into ageing have shown that an increasing number of older adults are independently living, mobile and active in their communities [2–4]. With increasing numbers of patients retaining natural teeth into old age, the challenge of providing oral healthcare for the ageing population is undoubtedly going to increase. An increase in exposed root surfaces in the over 65 age group predisposes this group to a higher prevalence of root caries than younger populations [5]. Estimating the prevalence of root caries can be challenging as loss of teeth confounds the data and diagnostic criteria and methods of reporting the data differ between studies [6–8].

A 2010 systematic review [9] on the risk indicators of root caries suggested that future research should focus on variables which they found to be significant across a number of studies. These included age, gender, number of teeth at baseline, plaque index, lactobacilli counts, mutans streptococci counts, smoking, saliva flow rate, saliva buffer capacity, dental visit pattern, race/ethnicity,

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interdental cleaning, attachment loss, partial denture wearing, and gingival recession.

The main objective of the present study was to investigate the relationship between root caries in a cohort of independently living older adults and the variables outlined above.

2. Materials and methods

2.1. Study design

The data reported in the present study were baseline recordings obtained at the beginning of a prospective longitudinal study conducted on the risk factors associated with root caries incidence in a cohort of independently living older adults. The study protocol was submitted and given full ethical approval by the Clinical Ethics Committee of the Cork Teaching Hospitals (ECM 4 Y 06/12/11). The study was conducted in compliance with the principles of the Declaration of Helsinki and written informed consent was obtained from each participant. Eighty-five of the individuals whose data are included in this report were also subsequently enrolled in a randomised controlled clinical trial comparing restorative materials in the operative treatment of root caries [10].

2.2. Recruitment

Adults aged over 65 years of age with any of their remaining natural dentition were invited to attend Cork University Dental School and Hospital for a free dental examination. Advertisements were placed in local shopping centres, community centres and the local press over a period of three months. Telephone contact details of the study co-ordinator were provided and patients were allocated appointments provided they were the appropriate age, and confirmed they had some of their natural dentition remaining. All of the patients recruited to the study were independently living older adults. No financial rewards were offered to patients. Recruitment commenced in October 2012 and was completed in November 2013.

2.3. Inclusion and exclusion criteria

The inclusion criteria for entering this study were:

- Aged 65 or over
- Present a minimum of one natural tooth
- Living independently in the community
- Have sufficient cognitive ability to understand consent procedures

The exclusion criteria for this study were:

- Those living in nursing home facilities
- Individuals requiring antibiotic prophylaxis for periodontal probing

2.4. Data collection and oral examination

Each participant was interviewed by a research assistant prior to the dental examination. During this, the research assistant completed a data collection form which recorded age, gender, education level, medical history, fluoride exposure, oral and denture hygiene practices, smoking and alcohol consumption, and diet information. The medical history form used was the standard form used throughout the dental hospital and the remaining questions were selected from the National Survey of Adult Oral Health 2000–2002 General Health Questionnaire [11]. The subject's health was classified into one of four categories based on a system developed by the American Society of Anaesthesiologists (ASA). In this classification:

- ASA 1 is a normal healthy patient without systemic disease.
- ASA 2 is a patient with mild to moderate systemic disease.
- ASA 3 is a patient with severe systemic disease that limits activity but is not incapacitating.
- ASA 4 is a patient with severe systemic disease that limits activity and is a constant threat to life.

A single trained and calibrated examiner performed a baseline oral exam in a standard dental operatory equipped with a dental light and air-water syringe. Patients were advised to avoid eating, drinking, smoking, chewing gum, tooth brushing, or mouthwashes for one hour prior to their appointment. Saliva was collected over a period of five minutes following one minute of stimulation by having the participant chew a paraffin pellet. Xerostomia was defined as a stimulated saliva flow rate of $<$ 0.7 ml saliva/min.

The CRT® Caries Risk Test (Ivoclar-Vivadent, Schaan, Liechtenstein) was used to record the salivary buffer capacity and counts of mutans streptococci (MS) and lactobacilli (LB). The buffer capacity of stimulated saliva was determined using CRT Buffer® (Ivoclar-Vivadent). The test field of the buffer strip was wetted entirely with stimulated saliva using a pipette. After 5 min of reaction, a coloured chart provided by the manufacturer was used to record the buffer capacity as low, medium or high. The MS and LB counts per millilitre saliva were recorded using CRT Bacteria® (Ivoclar-Vivadent). The agar surfaces were wetted with stimulated saliva and incubated at 37 °C (99 °F) for 48 h. The MS and LB counts were scored in two categories: $<10^5$ or $\geq 10^5$ CFU/ml saliva.

Plaque scores were recorded at baseline using the mucosal plaque score (MPS) index [12]. A WHO Basic Periodontal Examination (BPE) probe was used to evaluate the periodontal condition, the presence of calculus and loss of attachment. The diagnostic threshold for periodontal disease was any pocket in the patient's mouth where the black-band of a BPE probe (3.5–5.5 mm) partially or totally disappeared (i.e. BPE code 3 or greater). Denture wearing was recorded at baseline. Teeth were cleaned with an ultrasonic scaler, rubber cup and prophy paste and were washed and dried prior to caries detection. In this study, coronal caries visible into dentine, which had not cavitated but appeared as a definite shadow under the enamel (visual caries), was coded in the same manner as cavitated coronal caries. Decayed, missing and filled teeth (DMFT) were recorded. Root surfaces were anatomically defined as those surfaces apical to the cementoenamel junction (CEJ).

The root caries classification system used was a modification of the International Caries Detection and Assessment System (ICDAS II) [13] as described in Table 1. Each root surface was assigned two codes. The threshold applied to define a root surface as carious in this study was a Code 2 caries lesion code in combination with a Code 3 caries activity code, indicating a cavitated lesion of at least 0.5 mm depth which offers no resistance to probing with a ball-ended BPE probe. Secondary caries around an existing root surface restoration was scored in the same manner as a primary carious lesion.

2.5. Statistical analyses

Data from case report forms were entered into SPSS (version 22; SPSS, Inc., an IBM Company, Chicago, IL, USA) software. Fifteen participants were re-examined one week after initial exam. Intra-examiner reproducibility at root surface level was measured by the kappa statistic which was 0.95 for root caries detection indicating

Table 1
Modified international caries detection and assessment system (ICDAS II).

Caries lesion code		Caries activity code	
M	Tooth is missing	M	Tooth is missing
E	Root surface cannot be visualised	E	Root surface cannot be visualised
F	Root surface is filled and sound	F	Root surface is filled and sound
0	No discolouration or loss of contour	0	Caries free
1	Discoloured but no cavitation	1	Arrested; Smooth, shiny and hard
2	Discoloured with cavitation (≥0.5 mm)	2	Quiescent; Leathery to gentle probing
		3	Active; No resistance to gentle probing

high rater reliability. DMFT scores were calculated from a maximum of 32 teeth. Decayed and filled root surfaces (RDFS) was calculated by adding the number of decayed and the number of filled root surfaces. A filled root surface which had secondary decay was categorised as a decayed root surface. Root caries index (RCI) was calculated as follows, [(number of decayed root surfaces) + (number of filled root surfaces)]/(total number of sound and decayed exposed root surfaces) × 100 [14]. The data were described in bivariate tables. Normality was assessed by histograms, normal Q–Q plots, skewness values and their standard errors. For normally distributed data or normally distributed transformed data compartisons were made using a tw-sample *t*-test. Otherwise the non-parametric tests Mann Whitney *U* or Kruskal-Wallis were performed. *P*-values less than 0.05 were considered statistically significant.

Univariate and multivariate logistic regression analyses with the proportion of individuals with root caries experience (filled root surfaces or active root caries lesions) as the dependent variable were undertaken. This variable was dichotomized; subjects with RDFS > 0 were given a value of 1, and those with an RDFS = 0 were given a value of 0. The independent variables included were age, gender, final level of education, ASA category, alcohol consumption, smoking, fluoridated water supply, denture wearing, dental attendance, plaque control, tooth brushing frequency, interdental cleaning, periodontal disease, xerostomia, saliva buffering capacity, strep mutans count, lactobacilli count, number of teeth with coronal decay, number of missing teeth, number of teeth with coronal restoration, and number of exposed root surfaces. The continuous variables (number of teeth with coronal decay, number of missing teeth, number of teeth with coronal restorations, and number of exposed root surfaces) were dichotomized using the last quartile of the frequency distribution of that variable as the cut-off point. This reduced the continuous variables (which were recorded as a numerical value) into categorical variables to facilitate entry into the regression analyses.

The final model was chosen based on the backward elimination process, starting with the full independent variables, followed by subsequent removing of nonsignificant individual independent variables until no other nonsignificant independent variable could be removed.

3. Results

The characteristics of study participants are summarized in Table 2. 334 independently living dentate older adults participated in this study. 148 (44.3%) were male and 186 (55.7%) were female. The median age was 68 (IQR 66, 72) years. 136 (40.7%) were denture wearers and 24 (7.2%) were xerostomic. The percentage of the cohort with any root caries experience (filled or decayed) was 53.3% and 25.7% had two or more carious root lesions. The median number of exposed root surfaces was 20 (IQR 28, 37). The median RCI was 3.13 (IQR 0.00, 13.92). The distribution of RCI was highly skewed as shown in Fig. 1.

Means of continuous variables for participants with and without and root caries experience are reported in Table 3. Table 4 presents mean root caries experience by categorical variable and differences between groups were evaluated for statistical significance. In these analyses, participants with root caries were likely to be older, have more missing teeth, more teeth with coronal decay, a higher DMFT score and more exposed root surfaces than those individuals who did not have any root caries experience (Table 3).

Table 2
Characteristics of study participants (N = 334).

Variable	Category	n	%
Gender	Male	148	44.3
	Female	186	55.7
Denture wearing	Yes	136	40.7
	No	198	59.3
Xerostomia	Yes	24	7.2
	No	310	92.8
ASA category	ASA 1	108	32.3
	ASA 2	146	43.7
	ASA 3	80	24.0
Level of education	Primary Level	39	11.7
	Second Level	143	42.8
	Third Level	152	45.5
Alcohol consumption	None	109	32.6
	Less than 10 units/week	182	54.5
	More than 10 units/week	43	12.9
Smoking status	Smoker	58	17.4
	Past smoker	92	27.5
	Never smoked	184	55.1
Fluoridated water	Yes	231	69.2
	No	90	26.9
	Unsure	13	3.9
Interdental cleaning	Never	239	71.6
	Occasionally	60	18.0
	Daily	35	10.5
Frequency of brushing	Less than once a day	105	31.4
	At least once a day	229	68.6
Dental attendance	Regular attender	153	45.8
	Irregular attender	181	54.2
Periodontal condition	No periodontal disease	141	42.2
	Periodontal disease	193	57.8
Plaque control	Good oral hygiene	136	40.7
	Fair oral hygiene	118	35.3
	Poor oral hygiene	80	24.0
Lactobacilli count	High	172	51.5
	Low	162	48.5
S. mutans count	High	190	56.9
	Low	144	43.1
Saliva buffering capacity	Low	54	16.2
	Medium	150	44.9
	High	130	38.9

Continuous variables	Median (IQR)	Mean (SD)
Age	68 (66,72)	69.11 (4.26)
Decayed Missing Filled Teeth (DMFT)	24 (20, 27)	23.45 (4.99)
Number of missing teeth	10 (8, 16)	12.01 (6.06)
Exposed root surfaces	28 (20, 37)	29.72 (14.89)
Root Decayed Filled Surfaces (RDFS)	1.00 (0.00, 4.25)	3.35 (5.70)
Root Caries Index (RCI)	3.12 (0.00, 13.92)	9.50 (14.78)

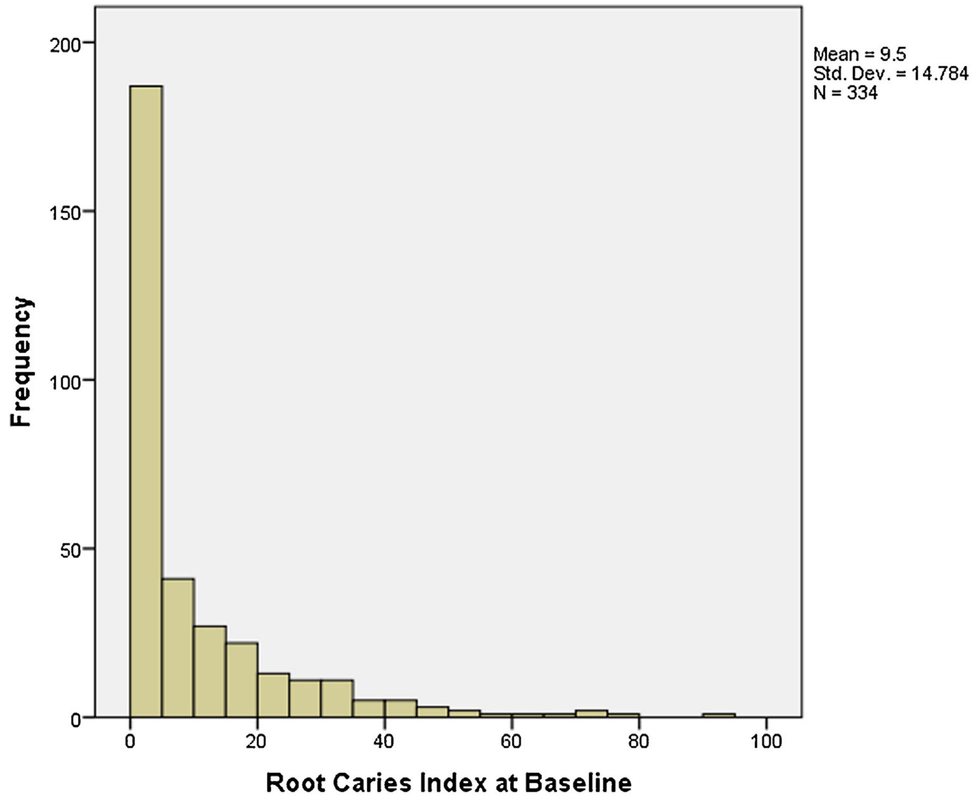

Fig. 1. Distribution of root caries index (%).

Table 3
Means and standard deviations (in parenthesis) of continuous variables for participants with (N = 178) and without (N = 156) any root caries experience (RCI > 0).

Variable	Participants with root caries	Participants without root caries	Mean difference (SE)	*p* value
Age, years	70.33 (4.78)	67.72 (3.05)	2.62 (0.44)	<0.001[a]
Number of missing teeth	13.11 (6.08)	10.74 (5.80)	2.37 (0.65)	<0.001[b]
Number of teeth with coronal decay	1.87 (2.54)	0.39 (1.16)	1.48 (0.21)	<0.001[a]
DMFT	25.01 (4.64)	21.67 (4.79)	3.34 (0.52)	<0.001[c]
Number of exposed root surfaces	35.44 (15.46)	23.21 (11.10)	12.23 (1.46)	<0.001[b]

[a] Mann-Whitney *U* Test.
[b] *T*-test for square root transformed data.
[c] Welch test for reflected square root transformed data.

Univariate non-parametric tests showed that significantly higher RCI scores were observed in those aged 70 or above, removable dental prosthesis wearers, xerostomic individuals, those who did not brush their teeth daily and those who had poor plaque control.

The results of the logistic regression analyses are reported in Table 5. A statistically significant association ($p < 0.05$) was shown in the bivariate analysis for the variables of; age (≥70 years), poor plaque control (reference was good or fair plaque control), tooth brushing less than once a day, xerostomia, moderate buffering capacity (reference was high buffering capacity), the presence of two or more teeth with coronal decay, ≥16 missing teeth and ≥37 exposed root surfaces.

The multivariate logistic regression analyses revealed that the odds of having root caries experience are increased in individuals with poor plaque control (OR 9.59; 95% CI 3.84–24.00), two or more teeth with coronal decay (OR 4.50; 95% CI 2.02–10.02), and ≥37 exposed root surfaces (OR 5.48; 95% CI 2.49–12.01). Those with xerostomia as measured by stimulated saliva flow <0.7 ml/min were also at a greatly increased risk of root caries. (OR 18.49; 95% CI 2.00–172.80).

Table 6 demonstrates the final prediction model. The variables age (≥70 years), poor plaque control, xerostomia, teeth with coronal decay (≥2) and exposed root surfaces (≥37) were included. This model classified correctly 77.5% of cases, with sensitivity 77.5%, specificity 77.6%, positive predictive value 79.8%, negative predictive value 75.1%. The model as a whole explained between 34.3% (Cox and Snell R square) and 45.7% (Nagelkerke R squared) of the variance in root caries experience. The chi-square value for the Hosmer-Lemeshow Test is 7.83 with a significance level of 0.17. This value is larger than 0.05 therefore indicating support for the goodness of fit of this model.

4. Discussion

The objective of this study was to identify variables significantly associated with root caries with the ultimate goal of helping to identify which individuals or groups of individuals are suitable for targeted root caries prevention strategies. These individuals will also be followed up in a prospective study to observe new root caries development and identify associated risk indicators.

Table 4
Mean root caries experience by categorical variable (N = 334).

Variable	*RDFS* *Mean (SD)*	% with RCI > 0	*RCI%* *Median (Q3)*	*p-value*
Gender				
Male	3.58 (6.01)	50.7	2.64 (15.11)	ns[a]
Female	3.16 (5.46)	55.4	3.64 (13.33)	
Age				
<70	2.16 (4.77)	42.6	0.00 (8.60)	<0.001[a]
≥70	5.34 (6.55)	70.4	8.10 (21.39)	
Education level				
Primary	5.33 (8.02)	64.1	6.45 (23.73)	ns[b]
Secondary	2.78 (5.19)	49.0	0.00 (10.00)	
Third	3.38 (5.38)	53.9	0.00 (14.82)	
ASA category				
1	3.35 (5.69)	52.8	3.12 (13.47)	ns[b]
2	3.45 (5.79)	56.2	3.70 (14.46)	
3	3.15 (5.63)	47.5	0.00 (14.16)	
Alcohol intake				
None	3.80 (6.48)	57.8	3.57 (14.04)	ns[b]
<10 units/week	3.03 (5.22)	49.5	1.19 (13.38)	
≥10 units/week	3.53 (5.66)	55.8	0.00 (16.67)	
Smoking				
Smoker	4.34 (6.90)	55.2	3.94 (21.24)	ns[b]
Past smoker	2.79 (4.38)	52.2	3.23 (13.72	
Never smoked	3.31 (5.87)	52.7	2.90 (12.95)	
Fluoridated water[*]				
Yes	3.08 (5.30)	48.9	0.00 (12.96)	ns[a]
No	3.81 (6.36)	61.1	5.20 (16.22)	
Denture wearing				
Yes	4.56 (6.89)	60.3	5.23 (18.71)	0.001[a]
No	2.52 (4.56)	48.0	0.00 (9.09)	
Dental attendance				
Regular	3.37 (5.49)	54.2	3.57 (14.84)	ns[a]
Irregular	3.33 (5.89)	51.9	2.94 (13.04)	
Plaque control				
Good	1.32 (3.03)	30.1	0.00 (3.70)	<0.001[b]
Fair	3.01 (5.07)	54.2	3.57 (13.06)	
Poor	7.29 (7.79)	90.0	14.96 (31.96)	
Tooth brushing				
<once a day	3.86 (6.15)	62.9	4.00 (18.71)	0.029[a]
≥once a day	3.11 (5.49)	48.5	0.00 (13.04)	
Interdental cleaning				
Never	3.28 (5.71)	55.2	3.57 (13.79)	ns[b]
Occasionally	3.28 (5.18)	51.7	2.94 (14.92)	
Daily	3.91 (6.63)	40.0	0.00 (16.98)	
Periodontal disease				
Yes	3.74 (5.84)	56.0	3.70 (14.29)	ns[a]
No	2.81 (5.49)	48.9	0.00 (13.31)	
Xerostomia				
Yes	11.08 (10.87)	95.8	20.95 (45.65)	<0.001[a]
No	2.75 (4.61)	49.7	1.19 (12.27)	
Saliva buffering capacity				
Low	5.13 (7.64)	53.7	5.67 (20.87)	ns[b]
Medium	3.17 (5.64)	57.3	3.57 (13.38)	
High	2.81 (4.65)	47.7	0.00 (11.33)	
Mutans streptococci				
<10^5 CFU/ml saliva	3.01 (4.78)	52.1	2.99 (15.11)	ns[a]
≥10^5 CFU/ml saliva	3.58 (6.32)	53.7	3.70 (13.33)	
Lactobacilli				
<10^5 CFU/ml saliva	3.41 (5.30)	54.9	3.64 (14.56)	ns[a]
≥10^5 CFU/ml saliva	3.29 (6.08)	51.2	2.90 (13.28)	

[a] Mann-Whitney *U* Test.
[b] Kruskal-Wallis test.
[*] 13 participants unsure, excluded from this analysis.

Participants in this study are independently living, with basic self-care ability and no serious medical problems and are typical of those patients that will increasingly be seen in general dental practices as the population ageing trend continues.

This study did not identify an association between root caries experience (having at least one active carious lesion on a root surface or a restoration on a root surface) and gender, education level, ASA category, alcohol intake, smoking, fluoridated water supply, dental attendance patterns, interdental cleaning habits, periodontal disease, saliva buffering capacity, mutans streptococci levels and lactobacilli levels. Previous studies have identified race and ethnic background as potential risk indicators however this could not be investigated in this study as all participants were white/Caucasian. The multivariate logistic regression analysis identified four significant variables; poor plaque control (with good or fair plaque control as the reference category), xerostomia, the presence of at least two teeth with coronal decay, and a high number of exposed root surfaces (≥37).

It is unsurprising that the presence of coronal decay and high plaque levels were identified as correlates for root caries experience as they are traditional markers for caries risk and have been identified as risk indicators previously [9]. It is also logical that an increased number of exposed root surfaces increases the potential for these surfaces to develop caries. Interestingly however, periodontal disease was not significantly associated with root caries experience. This highlights that both exposed roots in combination with poor plaque control creates a favourable environment for root caries. The risk factor of exposed root surfaces itself can be mitigated by good plaque control. Xerostomia greatly increases an individual's risk of root caries, however only 7.2% of participants in this study were in this category. This is likely to account for the wide confidence interval reported for this variable (Table 5). The reported prevalence of xerostomia in the general public ranges from 5.5% to 39%, and the prevalence among community-dwelling elders has been reported as ranging from 17% to 40% [15].

The Health (Fluoridation of Water Supplies) Act, was introduced in Ireland in 1960 and since then almost 70% of the public water supply in Ireland has been fluoridated. Initially the fluoride content in Irish drinking water was one part per million (ppm), but this was subsequently reduced in 2007 to between 0.6 and 0.8 ppm to reduce the risk of fluorosis. A previous study published in 1993 reported on the prevalence of root caries in Irish adults [7]; 94 of the participants were dentate and aged over 65. This study reported the mean RCI of dentate over 65 year olds as 11.7 for those living in fluoridated areas and 18.9 for those living in a non-fluoridated area. This study found that older adults living in a non-fluoridated area also had a higher median RCI (5.20, Q3 16.22) than those living in a fluoridated area (0.00, Q3 12.96) but this difference did not reach statistical significance. A limitation of this study is that data was gathered on the water supply of participant's current residence but not their life long exposure to water fluoridation. Previously published studies have found that water fluoridation is associated with lower levels of root caries [16,17].

Denture wearing was found to be significantly associated with root caries experience in univariate testing in this study but it did not emerge as a significant variable in the multivariate testing or the final prediction model. Previous studies have identified removable prosthesis wearing as a risk factor for root caries [18,19]. It is possible that close proximity to a removable prosthesis is a tooth level risk factor rather than a patient level risk indicator and warrants further investigation.

With reference to the sampling method (only those who chose to respond to advertisements) the study group examined was not representative of the general population. Thus, our data must be interpreted with caution as they relate only to self-selecting community-dwelling older adults. Inclusion of those who are institutionalized would have had the greatest impact on the root caries experience as the prevalence of dental disease is very high in this group [20–22]. It is also reported that persons with a less favourable attitude to oral care are probably less inclined to participate in an epidemiologic study [23]. The most recent national oral health survey conducted in Ireland (between 2000 and 2002) reported the mean number of teeth present in dentate over 65 year olds was 14.3 [11] while the mean number of teeth in

Table 5
Logistic regression analyses with root caries experience (RDFS > 0) as the dependent variable.

Variable[a]	Simple OR	95% CI	P-value	Multivariate OR	95% CI	P-value
Sociodemographic						
Gender (female)	1.21	0.78–1.86	ns	1.52	0.81–2.87	ns
Age (≥70 years)*	3.33	2.07–5.36	<0.001	1.74	0.91–3.33	ns
Final level of education (primary)	1.66	0.83–3.31	ns	1.65	0.60–4.54	ns
General Health Related						
ASA category (2)	1.18	0.71–1.94	ns	1.45	0.71–2.96	ns
ASA category (3)	0.81	0.45–1.44	ns	1.24	0.55–2.83	ns
Alcohol (>10 units/week)	1.12	0.59–2.14	ns	1.30	0.51–3.32	ns
Smoking (current smoker)	1.10	0.62–1.94	ns	0.73	0.30–1.77	ns
Oral Health Related						
Fluoridation (non-fluoridated water)	1.61	0.98–2.65	0.06	1.31	0.65–2.65	ns
Denture wearing (yes)*	1.61	1.04–2.51	0.03	1.11	0.57–2.14	ns
Dental attendance (irregular)	0.93	0.61–1.43	ns	1.11	0.61–2.02	ns
Plaque control (poor)**	12.57	5.81–27.19	<0.001	9.59	3.84–24.00	<0.001
Tooth brushing (<once a day)*	1.77	1.10–2.84	0.02	1.20	0.61–2.33	ns
Interdental cleaning (never)	1.31	0.82–2.12	ns	0.96	0.48–1.91	ns
Periodontal disease (yes)	1.29	0.83–1.99	ns	1.50	0.81–2.79	ns
Saliva Related						
Xerostomia (yes)**	23.00	3.07–172.42	0.08	18.49	2.00–172.80	0.01
Saliva buffering capacity (moderate)*	1.51	0.94–2.43	0.002	0.97	0.41–2.27	ns
Saliva buffering capacity (low)	1.27	0.67–2.40	ns	1.40	0.73–2.70	ns
Strep mutans count (high)	1.04	0.62–1.60	ns	0.60	0.32–1.13	ns
Lactobacilli count (high)	0.88	0.57–1.35	ns	0.93	0.50–1.74	ns
Past disease experience						
Teeth with coronal decay (≥2)**	8.66	4.65–16.16	<0.001	4.50	2.02–10.02	<0.001
Missing teeth (≥16)*	1.65	1.00–2.70	0.048	2.04	0.89–4.71	ns
Number of coronal restorations (≥15)	0.96	0.60–1.55	ns	1.90	0.87–4.17	ns
Exposed root surfaces (≥37)**	5.67	3.12–10.32	<0.001	5.48	2.49–12.01	<0.001

[a] Reference categories for each variable are those described in Table 4.
* Significant in univariate analysis ($p<0.05$).
** Significant in univariate and multivariate analysis ($p<0.05$).

Table 6
Prediction model for root caries experience (RFDS > 0).

Independent variables	Coefficient	Standard error	*p*-value	OR	95% CI
Age (≥70 years)	0.61	0.30	0.04	1.84	1.03–3.31
Plaque control (poor)	2.27	0.42	<0.001	9.68	4.23–22.16
Xerostomia	2.93	1.08	0.007	18.76	2.27–155.05
Teeth with coronal decay (≥2)	1.52	0.36	<0.001	4.56	2.25–9.24
Exposed root surfaces (≥37)	1.45	0.35	<0.001	4.28	2.15–8.51
Constant	−1.29	0.20			

participants of this study was 20.0. However there was no statistically significant difference between the mean DMFT (25.9) and mean RCI (11.6) of dentate 65+ year olds in the national oral health survey (25.9) and the mean DMFT (23.45) and RCI (9.5) of our sample.

Comparing the results of this study to previously reported studies is challenging with respect to the definition used for root caries. Contrary to the WHO criteria for diagnosis of dental caries, a number of studies make a distinction between primary and recurrent caries [24]. The diagnostic threshold for root caries applied in this study was particularly high requiring the root surface to be both cavitated and also soft, offering no resistance to probing with a ball ended probe. Other studies classified a lesion as active if it was softened or leathery on moderate probing with a sharp explorer probe [24,25]. Some studies calculated RCI by including both active and inactive lesions as root caries while this study treated inactive lesions as sound exposed root surfaces in statistical calculations [25]. Many studies do not describe in detail the criteria applied when categorising a lesion as active or inactive and do not specify whether inactive lesions were included as root caries lesion in the calculation of RCI and RDFS [26,27]. There is also considerable variation in examination conditions as some dental examinations included removal of calculus and air drying of teeth prior to examination of root surfaces and some did not [27,28]. Therefore, while published studies include calibration of examiners and report good inter and intra-examiner reliability, examiners working on different studies are working to different criteria for root caries diagnosis and working under different examination conditions. This (combined with differences in geographic location, population characteristics and sampling procedures) may explain the variability in reported root caries experience between studies with some studies reporting a root caries prevalence of 100% [29] and others reporting 25% [8].

5. Conclusions

This study suggests that root caries is more likely to be detected in individuals with poor plaque control, a high DMFT score, coronal caries, a high number of exposed root surfaces and xerostomia. These risk indictors should be examined in a prospective cohort study to confirm their association with the development of new root caries. There is a need for greater consensus on the diagnostic criteria and definition of active root caries and the calculation of root caries indices to allow comparison between reported studies.

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